5.0 Summary

Two important categories of roadway departure crashes were identified in Task lof this program, crashes caused primarily by failures in lateral control, and crashes caused primarily by failures in longitudinal control. Lateral crashes account for at least 32.8 percent of all roadway departure crashes, and typically result from driver inattention, driver incapacitation, and to some extent, lose of directional control. Longitudinal crashes account for at least 32.0 percent of all roadway departure crashes. These crashes often occur on curves, and are usually precipitated by excessive speed for the road geometry or pavement conditions. These includes crashes identified in Task 1 as being caused by excessive vehicle speed or lost directional control.

Functional goals were developed in Task 2 for these two crash types. The goals represent actions a countermeasure would need to perform in order to prevent each type of crash. In Task 3, the effort documented in this report, technology with the potential to fulfill these functional goals was identified and tested. While no commercially available countermeasures were identified which performed all the functional goals required for either a lateral or a longitudinal countermeasure, the project team was able to acquire component technologies for accomplishing most of the individual functional goals. The team was able to combine these components into working prototypes of both lateral and longitudinal countermeasures for testing.

Three types of tests were performed on the individual components and the complete countermeasure systems - laboratory tests, in-vehicle tests, and driving simulator tests. The laboratory tests were preformed primarily on the sensing components to measure sensing accuracy and repeatability. In-vehicle tests were performed to tests sensing and processing algorithms under realistic conditions. The driving simulator tests were conducted primarily to measure the performance of the driver interface components of the lateral and longitudinal countermeasures. The results of the laboratory and in-vehicle tests of the sensing and processing technology are described in Volume I of this report, and the results of the interface experiments on the driving simulator are presented in Volume II.

5.1 Lateral Technology Tests

The most challenging functional goal for a countermeasure to prevent lateral roadway departures is to reliably and accurately determine the vehicle’s position relative to the roadway. Tests were conducted on three sensing technologies designed to perform this function. One of them, the AURORA system, uses a downward looking video camera to track lane markings next to the vehicle. AURORA determines the vehicle’s position in the lane by measuring the distance between the vehicle’s tires and the lane marking. Laboratory and in-vehicle tests of the AURORA system indicate that it can estimate the lateral position of the vehicle with about lcm accuracy. Tests showed AURORA to be relatively insensitive to ambient lighting and road condition. However AURORA is limited to roads with distinct painted lane markings; and has difficultly when the markings are severely degraded, obscured or missing. Also, AURORA does not have forward preview capability, resulting in occasional false alarms when negotiating curves.

Two vision systems with forward preview capabilities were also tested, the ALVINN and RALPH systems. These two systems adapt their processing to the features available, and can therefore handle roads on which the lane markings are degraded, obscured, or missing. These two systems detect the road ahead of the vehicle, and can therefore anticipate curves better than AURORA. However, as systems with forward looking sensors, they are somewhat more sensitive than AURORA to harsh weather and lighting conditions. Tests showed that ALVINN can handle reduced visibility from rain and/or fog down to about 300m, but below that visibility level, performance begins to degrade. Other difficult situations for forward looking systems like ALVINN and RALPH are when the sun shines directly into the camera at dawn and dusk. Locating the road at night, using only headlights for illumination, was not a problem for these forward looking systems. Overall, the RALPH system was shown to be capable of locating the position of the road ahead of the vehicle to a distance of approximately 60m with an accuracy of about 12cm on a wide variety of road types and environmental conditions.

One functional goal for which there appears to be little existing technology is detection of driver intention. An effective lateral countermeasure must be able to discriminate between inadvertent lane departures due to driver inattention or impairment and intentional lane departures which occur when changing lanes or turning onto a cross street. Further work is required before countermeasures will be able to perform this important function.

5.2 Longitudinal Technology Tests

The most challenging functional goals for a countermeasure designed to warn of excessive speed are determining the geometric characteristics of the upcoming road segment, and detecting degraded roadway conditions. The tests conducted for this effort indicate the former of these goals can be performed satisfactorily using vehicle position estimates provided by differential GPS, in combination with an accurate digital map. Using these technologies, a longitudinal countermeasure can determine its position relative an upcoming curve to within approximately 12m. In the tests conducted, this position uncertainty typically resulted in variations in warning onset time of less than 0.5 seconds, which should be acceptable to drivers.

The second challenging functional goal for longitudinal countermeasures, detecting degraded roadway conditions, appears to be more difficult. Infrastructure-based systems for detecting wet or icy pavement exist and appear from our tests to be capable of providing useful pavement condition data. However these systems are currently very expensive and would probably not be practical for widespread deployment. In addition, no algorithms appears to exist for accurately converting pavement condition information into an estimate of coefficient of friction, which is the important parameter for a longitudinal countermeasure.

An alternative are vehicle-based techniques for estimating the instantaneous coefficient of friction. By monitoring the dynamics of the vehicle and the forces being applied to the tires, it appears possible to estimate the coefficient of friction quite accurately, to within 0.05 to 0.1. However this technique has been demonstrated only in simulation, and still needs to be verified in experiments on real vehicles. In addition, at best this approach can only detect degraded roadway conditions once the vehicle has encountered them. By then it may be too late to avoid a crash.

Fortunately, nearly 2/3rds of all vehicle speed related crashes occur on dry pavement. A countermeasure which relies on only a coarse estimate of available friction has the potential to prevent the majority of longitudinal crashes. Further work is required to develop these friction modeling algorithms, and to verify they are sufficient for an effective countermeasure.

5.3 Driver Interface Tests

A crucial functional goal of all collision countermeasures is to effectively interact with the driver. A system must be capable of conveying the danger of collision to driver in a manner that elicits an appropriate response in emergency situations, and does not significantly increase the driver's workload during normal driving. Tests on the Iowa driving simulator suggest several interface configurations can achieve these goals. Below is a brief summary of the simulator experiment results. For more details, see Volume II of this report.

In general, neither the lateral nor the longitudinal countermeasures appear to significantly increase driver workload during normal driving. Either haptic (tactile) or auditory interfaces appear to be viable means of providing the driver with feedback. However, the combination of both modalities can result in driver overload. Directional feedback, which provides information about the appropriate driver response, is preferred by drivers, and appears to provide at least some performance benefit. Early onset of warnings seems to have a beneficial effect on collision avoidance maneuvers, particularly for the lateral countermeasure. However the less frequent feedback from late onset warnings was subjectively preferred by the test subjects.

In probably the most striking findings of these experiments, 3 1 percent (5 / 16) of the control subjects without road departure countermeasure support crashed when presented with a lateral disturbance (a simulated wind gust) while distracted from the drive task. In the same circumstances, only 8 percent (4 / 48) of the driver's with lateral countermeasure support were unable to avoid a crash. These result suggest that lateral countermeasures may indeed be effective at preventing roadway departure crashes. Unfortunately, such dramatic results were not observed in the longitudinal experiments, where none of the 64 subjects crashed due to excessive speed through curves. This was probably due to the conservative driving style of subjects in the simulator and the difficulty of creating dangerous longitudinal roadway departure situations in the simulator.

5.4 Conclusions

Tests of roadway departure collision avoidance technology conducted for Task 3 indicate that while no complete countermeasures are currently commercially available, the technology for such countermeasures exists. Further work is required to refine and integrate this technology into effective collision avoidance systems. Additional experiments and analysis is also required to quantify the level of performance that such integrated countermeasures could achieve. The tools developed in Task 3 will be valuable assets in the development of performance specifications for run-off-road countermeasure to take place in the remainder of this program.